Soil Stabilization with Cement

Presented to:
APWA NorCal Conference

450 Civic Center St.
Richmond, CA 94804
November 3, 2016

Presented by:
Jeff Wykoff
Engineered Applications Manager, CNCA
Hans Stadem
Paving Solutions Engineer, Cemex

Get More Mileage from Every Dollar in Your Paving Budget
AGENDA

• The Problem: Unsuitable Soils
• The Solution: Soil Stabilization
• What is Soil Stabilization
  • Chemistry Changes
  • Physical Changes
  • Engineering Property Changes
• Mix Design
• Placement and Mixing: The Story of Acacia
• Revising Your Original Design: The Story of Long Beach
• Lightweight Cellular Concrete
THE PROBLEM: POOR QUALITY “UNSUITABLE” SOILS

- Exhibit Poor Pavement Support
  Low R-values & Unconfined Compressive Strength

- Typically Moisture Sensitive
  Expansion Potential & Swell Pressure

- Constructability Issues
  “Pumping” - Poor Workability
  Not Readily Compactable

Typical Poor Quality Soil
Remediation of Unstable Subgrade

- Scarify, aerate, & re-compact
- Remove unstable, pumping soil and replace with geotextile fabrics and base

Structural Design Applications

- Remove low R-value soil and replace with base
- Thicker asphalt pavement structural sections
- Interlayer grid systems
THE SOLUTION: SOIL STABILIZATION

Portland Cement
CEMENT STABILIZATION APPLICATIONS

- Reduce PM-10 & Improve Air Quality
- Conserve Existing Resources & Save $$
- Reuse Materials In Place & Save $$
- Increase TI In Same Depth & Save $$
- Reduce Thickness For Same TI & Save $$
- Reduce Construction Traffic On Area Roads & $$
- Reduce Material Sent To Landfill & Save $$
- Minimize Noise and Disruption & Save $$
- Stabilize Site in Wet Weather, Save Time and $$
SOIL STABILIZATION IS THE TREATMENT OF POOR SOILS THAT ARE INADEQUATE FOR CONSTRUCTION

1. What is it?
   - Mixing calcium based additives into the soil
   - Increases workability, strength, compaction
   - Reduces moisture susceptibility

2. How does it work?
   1. Calcium + Silica (Clay) = CSH
   2. Calcium + Alumina (Clay) = CAH
   3. Cement + H₂O = CSH + Hydrated Lime

   CSH + CAH = Strength Gain

3. What are the Typical products Used?
   1. Low PI: Cement, fly ash, asphalt
   2. Mid PI: Lime, cement, fly ash, other products
   3. High PI: Lime, Lime-cement, cement, fly ash

(1) PI – Plasticity index – measure of soil plasticity. Low PI = Sand, High PI = Clay
(2) Majority of soil stabilization is done on mid to high PI soils
### Difference in Chemistry Between Lime and Cement

<table>
<thead>
<tr>
<th></th>
<th>Lime</th>
<th>Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Particle Restructuring</strong></td>
<td>Calcium atoms flocculate the clay structure increasing workability, strength, and compaction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100% Calcium</td>
<td>66% Calcium</td>
</tr>
<tr>
<td><strong>2. Pozzolanic Reaction</strong></td>
<td>Hydrated Lime + Silica (Clay) = CSH</td>
<td>Hydrated Lime + Silica (Clay) = CSH</td>
</tr>
<tr>
<td></td>
<td>Hydrated Lime + Alumina (Clay) = CAH</td>
<td>Hydrated Lime + Alumina (Clay) = CAH</td>
</tr>
<tr>
<td></td>
<td>CSH + CAH = Strength Gain</td>
<td>CSH + CAH = Strength Gain</td>
</tr>
<tr>
<td><strong>3. Cement Hydration</strong></td>
<td>Does Not Occur with Lime</td>
<td>Cement + H₂O = CSH + Hydrated Lime</td>
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<tr>
<td></td>
<td></td>
<td>CSH = Strength Gain</td>
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</table>
Untreated clays have a layered particle structure. The structure can trap water between layers, causing volume and density changes.

Calcium atoms (from cement or lime) alter clay structure from flat – layered orientation to random edge to face orientation producing a granular type soil (Ion exchange).

The hydrated cement locks the particle together providing a permanent bound structure (Lime can do this at high percentages).
HIGH CALORICAL CRITICAL ELEMENT:
SOL I STABILIZATION REAGENTS FOR THE SPECTRUM OF SOIL TYPES

<table>
<thead>
<tr>
<th>Expansive</th>
<th>Non-Expansive</th>
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<tbody>
<tr>
<td>High Calcium Quicklime</td>
<td>Cement</td>
</tr>
<tr>
<td></td>
<td>Asphalt Bitumen/Emulsion</td>
</tr>
<tr>
<td></td>
<td>Combination of Reagents</td>
</tr>
</tbody>
</table>
SOIL STABILIZATION WORKS FOR HIGHLY PLASTIC CLAY SOILS

- Portland Cement Association (PCA) tested highly plastic clays from California and Texas

Before Treatment:
- PI = 25 – 37
- Shrinkage limit = 18 – 25
- UCS = 54 – 60 psi

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>Unconfined Compressive Strength (PSI)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>3% Cement</td>
</tr>
<tr>
<td>1</td>
<td>80-140</td>
</tr>
<tr>
<td>7</td>
<td>90-175</td>
</tr>
<tr>
<td>28</td>
<td>110-220</td>
</tr>
<tr>
<td>91</td>
<td>110-290</td>
</tr>
</tbody>
</table>
RECENT SOIL STABILIZATION PROJECTS R VALUE TEST RESULTS

Port Richmond  Bollinger Canyon  Oxnard  San Clemente  Fresno  Sacramento  Carlsbad

NATURAL SOIL
STABILIZED SOIL
TYPICAL STRENGTH CURVES FOR CEMENT TREATED BASES & SOILS

Strength (psi) vs. Cement (%)

- Soil-Cement
- CTB

0 2 4 6 8 10
Cement (%)
0 500 1000 1500 2000 2500
Strength (psi)
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SOIL STABILIZATION MIX DESIGN IS CONDUCTED WITH STANDARD TESTING

• Sieve Analysis (ASTM C136)
  • 100% Passing 3-inch Sieve
  • Minimum 95% Passing 2-inch Sieve
  • Minimum 55% Passing No. 4 Sieve

• Moisture-Density Relationship (ASTM D558)

• Compressive Strength (ASTM D1633)
  • Series at Different Cement Contents
  • Target is Generally 300 – 400 psi
  • Additional strength may be required if materials are moisture-sensitive or other factors demand higher strength.
  • “Balanced Design” provides sufficient strength without creating a brittle section.
MIX DESIGN – THE GOAL IS TO BE BALANCED

- More stabilizer is not necessarily better
- Determine “Target Level” to provide strength without sacrificing durability
- Typically 3-6%
QUALITY IS CONTROLLED WITH TRADITIONAL FIELD TESTING METHODS

Gradation/Uniformity

<table>
<thead>
<tr>
<th>Common Gradation Requirements</th>
<th></th>
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<tbody>
<tr>
<td>Sieve Size</td>
<td>Percent Passing</td>
</tr>
<tr>
<td>3 in.</td>
<td>100</td>
</tr>
<tr>
<td>2 in.</td>
<td>95</td>
</tr>
<tr>
<td>No.4</td>
<td>55</td>
</tr>
</tbody>
</table>

Density

- Common density requirement is to achieve at least 96% of the established laboratory standard Proctor density (ASTM D558).
- Measure wet density in direct transmission mode.

Depth of Stabilization

Common depth verification utilizes phenolphthalein indicator.

Moisture Content

Common moisture requirement is to be within 2% of the laboratory established optimum moisture content (ASTM D558).
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AGGREGATE SUSTAINABILITY IN CALIFORNIA

CALIFORNIA GEOLOGICAL SURVEY

AGGREGATE SUSTAINABILITY IN CALIFORNIA

Fifty-Year Aggregate Demand Compared to Permitted Aggregate Reserves

By
John P. Clinkenbeard (PG 4731)
2012

Legend:
- Fifty-year demand that is met by existing permitted reserves
- Fifty-year demand is 2.5 to 500 million tons
- Fifty-year demand is less than 2.5 million tons

GIS Design and Map Layout by
Milton Pimentel
ACACIA, ORANGETHORPE TO KIMBERLY
Fullerton, late 1980s

AC 5 in.  
AC: $0.850/sf

AB 16 in.  
AB: $0.826/sf

SUBGRADE  
Excav: $0.635/sf

Total  $2.31/sf
ACACIA, ORANGETHORPE TO KIMBERLY
Fullerton, late 1980s

AC 5 in.                      AC  0.85
FDR 9 in.                     Fabric 0.09
SUBGRADE                     Pulv 0.20
                            C-T 0.24
                Total $1.38/sf
ACACIA, ORANGETHORPE TO KIMBERLY
2004
BULK CEMENT LOADING
BULK CEMENT SPREADING
FIELD QUALITY CONTROL

- Cement spread rate application
- Depth of mixing
- Heel Out Around Manholes, Structures
- Moisture content
- Uniformity of mixing and particle sizing
- Compaction and moisture testing
- Post compaction curing – keep moisture in
SPREAD RATE INSPECTION

- **Check Point Inspection**
  Pan Method: Using a 3 sq. ft. pan, determine the spread rate in lb/sf.

- **Spread Rate Inspection**
  Confirm the area of coverage for each truck load of cement using the certified truck weights & design, spread rate.

*Courtesy HSI Engineering*
MIXING CEMENT WATER & PMB
DEPTH OF STABILIZATION INSPECTION

- Excavate test pit in treated section either loose or compacted

- Phenolthalein pH indicator solution. Color change at pH 8.5

- Spray solution along face of test pit to determine stabilized section bottom

- Check depth using grade stake elevations or measure compacted depth

- Courtesy HSI Engineering
Project was completed within one month. Full-depth asphalt reclamation with Portland cement will provide many years of service and is significantly less expensive than traditional reconstruction.
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Meeting Invitation for Discussion of Airfield Pavement Construction Costs
September 21, 2005
Page 2

completed questionnaire by the City is requested no later than Friday, October 14, 2005.
Comments and suggestions gathered through this process will be shared with consultants doing work for the Long Beach Airport, the FAA, and perhaps other Airports. If, for any reason, you wish for your information to be utilized only by Long Beach, please indicate so at the time of the meeting or on the questionnaire.
Your attendance at the meeting would be greatly appreciated. If you have any questions, please contact Rachel Korkos, Civil Engineer, at (562) 570-2620.

Sincerely,

Mark Christoffels
City Engineer

Attachments
sk pr/Mtg Invite to Contractors 9-20
Original Design
Asphalt Pavement 14"
Crushed Agg Base 22"
Fabric & Subgrade Prep 17"
Total 53"
(4.4’)
Revised Design
Partial Mill Asphalt (P-401) 5"
Pulverized M B (P-209R) 12.5"
“Soil Cement” sub (P-301) 18"
Total 35.5”
Benefits

Original Bid $28.5 Million
Revised Bid $22.0 Million
Savings $ 6.5 Million

Shorter Schedule
Jeffrey A Sedlak, P.E.
Aviation Engineer, City of Long Beach:

“The recycling processes, inclusive of the soil-cement, proved not only to be economically viable and environmentally-friendly, they have also provided for increased structural support in our airfield pavements”
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LIGHTWEIGHT CELLULAR CONCRETE (LCC)

BENICIA-MARTINEZ

SF-OBB WESTBOUND
COLTON CROSSING RR OVER RR GRADE SEPARATION
After placement and mixing, water is added (if dry mix) and the mixture is compacted with traditional compaction equipment.
Thank You & Any Questions?

Hans Stadem
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218-838-9921

Jeff Wykoff
Jeff.wykoff@cncement.org
949-689-6961
**HOW CONCRETE AND ASPHALT PAVEMENTS ARE DIFFERENT**

Concrete Pavements are rigid

- Loads are distributed over a large area through slab action
- Minor deflections
- Low subgrade contact pressures
- Subgrade uniformity is more important than strength

Asphalt pavements are flexible

- Loads are more concentrated
- Deflections are higher
- Subgrade, base and subbase strength are very important
- Usually require more layers and greater thickness for optimally transmitting load to the subgrade

Concrete’s Rigidity spreads the load over a large area and keeps pressures on the subgrade low

1. 7000 lbs load.
   - pressure ~3 - 7 psi

2. 7000 lbs load.
   - pressure ~15 - 20 psi